Chapter One

Introduction to Geographic Information System

Objectives of the Unit

After completing this unit, you should be able to:

➢ Define Geographic Information system (GIS).

➢ Discuss historical development of Geographic Information system.

➢ Explain the main objectives of GIS and its Core elements.

➢ Explain the main Components of Geographic Information system.

➢ Explain the main application areas of GIS

1. Introduction

The technology of GIS has developed so fast over the past few decades and now it is accepted as an essential tool for the effective use of geographic information.

Nowadays, there are many environmental problems like:

- Climate Change
- Unplanned Urbanization
- Soil erosion
- Deforestation
- Environmental degradation
- Drought
- Shortage of drinking water
- Political, Social, Economical

One of the problems to integrate these issues is the lack of means to link the data in comparable and manageable sets. So, in order to overcome these difficulties, GIS offers entry of many types of data in a single spatial framework and has capability of collection, storage, retrieval, analysis, manipulation, display and integration of environmental, economic and social data in a single system.

1.1 Concept and Definition of Geographic Information System

Geographic Information System can be defined as in many ways according to capability and purpose for which it is applied. In simple terms, GIS is a computer-based system for the capture, storage, manipulation, retrieval and display of spatial data. From Geographic Information System;

Geographic implies real world, spatial realities; Information is data and their meaning and, System is computer technology.

Why the term Geographic, Information and System?

• Geographic, because data collected is associated with some location in space.

• Information, because attributes or the characteristics (data), about the space is what we want to learn about.

• System, because there must be a tie from the information to the geography in a seamless operation.

A Geographic Information System (GIS) - is a tool for making and using spatial information. It uses the power of computer to pose and answer geographic questions. The user guides the program to arrange and display data about places on the planet in a variety of ways - including maps, charts and tables. The hardware and software allow the users to see and interact with data in new ways by blending electronic maps and databases to generate color-coded displays. Users can zoom in (enlarge) and out of (reduce) maps freely; add layers of new data, and study detail and relationships. It is also possible to define GIS as computerized system that functions for: data collection, data input, data storage, data manipulation, data analysis and data presentation (output) that helps in supporting decision makers to use it as a tool for decision making process.

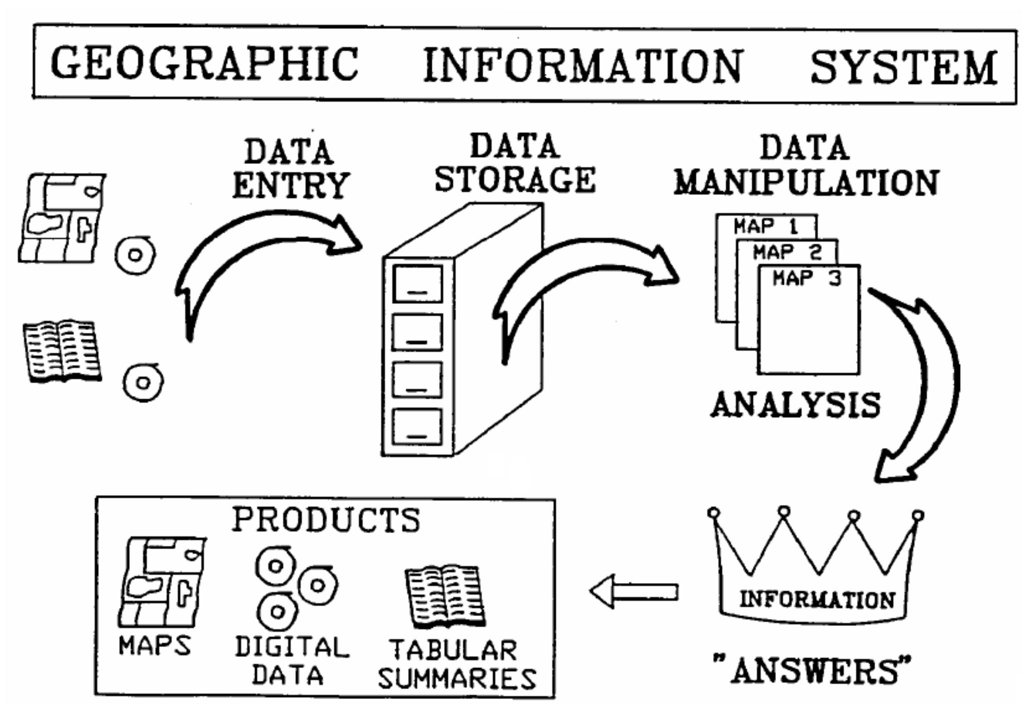

Fig 1. Interrelation between different functions of GIS

Sector Based Definitions of GIS

• GIS is a computerized tool for solving geographic problems for better decision support system (Planners and Decision-Makers)

• GIS is a container of maps in digital form (General Public).

• GIS is a mechanized inventory of geographically distributed features and facilities for better transportation and communication systems (Transportation/Utility Managers)

• GIS is a tool for revealing what is otherwise invisible in geographic information (Scientists or Researchers).

• GIS is a tool for performing operations on geographic data that are too tedious or expensive or inaccurate if performed by hand (Resource Managers/Planners).

However, GIS is more commonly defined as it is an information system that is used to input, store, retrieve, manipulate, analyze, and display of geographically referenced data and its correspondence attribute information in order to support decision making for the planning and management of land use, natural resource, environment, urban facilities, transportation and other administrative records.

GIS as a System and Science

The abbreviation GIS is commonly used for the Geographic Information Systems, while GIS science is used to abbreviate the science. The distinction is important, because the future development of GIS depends on progress in GIS science. Since GIS is the tool with which we solve problems, we are mistaken if we consider it as the starting and ending point in geographic reasoning "Geographic Information Science (GIS science) is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems. GIS science also examines the impacts of GIS on individuals and society, and the influences of society on GIS. GIS science re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science. Geographic information science (GIS science) is the academic theory behind the development, use, and application of geographic information systems (GIS). It is concerned with GIS hardware, software, and geospatial data. GIS, on the other hand, addresses problems and issues primarily through technological methodology (e.g. digital mapping), and GIS science addresses fundamental issues raised by the use of GIS and related technologies.

Links between the different terms in GIS

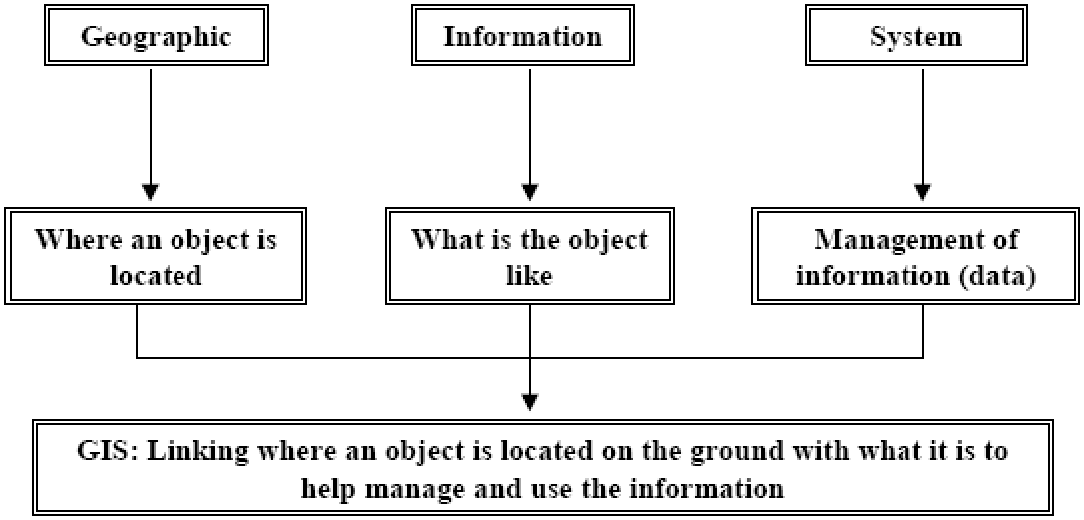

Fig 2. Links between the different terms in GIS.

1.2 Historical Development of GIS

The first true GIS developed was the Canadian GIS (CGIS) headed by Roger Tomlinson (father of GIS), which included the first digital land use maps of Canada. It was originated from computer -assisted cartography and supported by the development of computer technology such as CPU, printer/plotter, scanner, memory, GPS, communication

• Generally, the history of GIS is categorized in to three eras.

1) Era of Innovation (1957- 1977):

❖ It is the era where GIS is introduced to the world

❖ The most important events in the era of innovation were the foundation of ESRI (Environmental System and Research Institute) and the launch of land sat I.

2) Era of Commercialization (1981-1999):

❖ It is the era where GIS is used to make a business.

❖ The main events of this era were the launch of ArcInfo, introduction of GPS operation (It is used for navigation, surveying and mapping), and Internet GIS products.

3) Era of Exploitation (1999):

❖ It is the era where we are now

❖ It is distinct by a high number of GIS users

❖ Launch of IKONOS and QUICKBIRD satellites, and the introduction of Google earth and Mobile mapping.

Origin of GIS

In general, GIS has its origins in various disciplines as shown in Fig 3.

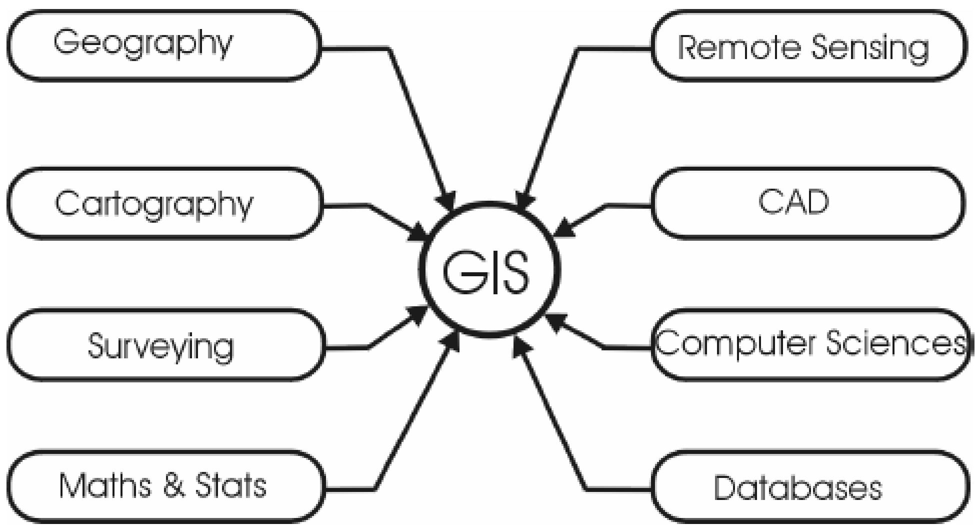

Fig 3. Development of GIS

Broadcasting GIS

➢ Internet websites

• www.gis.com

• www.spatialnews.com

• www.geocomm.com

• www.giscafe.com, Gis.about.com

1.3 Objectives of GIS

GIS is developed to:

➢ Maximize the efficiency of planning and decision making.

➢ Provide efficient means for data distribution and handling.

➢ Eliminate redundant database

➢ Enhance the integration of information from many sources.

➢ Provide complex analysis for decision making.

➢ Generate new information.

➢ Maintain data consistency.

Considering those objectives, GIS have different functions for the user like capturing data, storing data, querying data, analyzing data, displaying data and output data.

Capturing data: A GIS must provide methods for inputting geographic (coordinate) and tabular (attribute) data. The more inputs are available the more versatile the GIS.

Storing data: A GIS should able to store geographic data in both vector and raster data formats.

Querying data: A GIS must provide utilities for finding specific features based on their locations or attribute value.

Analyzing data: A GIS must have the ability to answer questions regarding the interaction of spatial relationships between multiple data sets.

Displaying data: There must be tools for visualizing the geographic features using a variety of symbology.

Output data: Raster of display should be outputs in variety of formats such as maps, tables, reports and graphs.

Why Use a GIS?

There are many reasons to use GIS in our day to day activities. The following are some of the reasons or benefits to use it.

• Information from many different places can be stored and analyzed in the same database (data integration).

Examination of spatial relationships and patterns is much easier

• Data stored in digital format, so physically more compact

• Large quantities of data can be maintained and retrieved at greater speeds

• Lower cost of maintaining and retrieving data

• Revision and updating are easier

• Data integration

• Capability of data processing and modeling

• Geospatial data and information are easier to search, analyze and represent

• Geospatial data can be shared and exchanged freely

• Time and money are saved

• New capabilities (database queries, overlays for new information)

• Linked graphic and non-graphic data

• Better, quicker, and more accurate answers for the public

Core elements of GIS

GIS has three main core elements: a) create geographic data, b) analyze data, and c) represent data

a) Create geographic data: Is the way to understand GIS data, know the types and characteristics of spatial data; to generate, organize, and document spatial data using different technologies

b) Analyze data: Is the way to understand analytical methods and use of them appropriately.

c) Represent data: Is the way to understand and use different classification methods and use different symbolization strategies.

The key feature of GIS is the analysis of data to produce new information. Due to its strong analysis, modeling and visualization capabilities, GIS provide answers for spatial questions.

1.4 Questions a GIS can answer

There is another way to describe GIS by listing the type of questions that the technology can (or should be able) to answer. These include: locations, conditions, trends, patterns, modeling, non-spatial questions, and spatial questions. There are five main types of questions that a GIS can answer:

Query for location: what is at………?

The first of these questions seeks to find out what exists at a particular location. Mapped data primarily indicates where objects are located, but cannot explain why. A location can be described in many ways, using, for example place name, postcode, or geographic reference such as longitude/latitude or x/y coordinates. For example, an aerial photo may show that corn is growing vigorously in certain sections of a field, but cannot explain why it does not grow well in other areas.

ii. Query for Condition: where is it…………?

The second question is the converse of the first and requires spatial data to answer. Frequently a GIS user wants to discover whether the mapped data will meet certain conditions. That means instead of identifying what exists at a given location, one may wish to find location(s) where certain conditions are satisfied (e.g., an un forested section of at-least 2000 square meters in size, within 100 meters of road, and with soils suitable for supporting buildings).

iii. Trend analysis: what has changed since…………..?

The third question might involve both the first two and seeks to find the differences (e.g. in land use or elevation) over time. This can help to address temporal changes of earth's phenomena.

iv. Pattern analysis: what spatial patterns exist…………..?

This question is more sophisticated. One might ask this question to determine whether landslides are mostly occurring near streams. It might be just as important to know how many anomalies there are those do not fit the pattern and where they are located.

v. Modeling: what if……………..?

"What if…" questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local ground water supply. Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operation.

In addition to all these capabilities, GIS can also handle related to non- spatial issues. For instance, "What's the average number of people working with GIS in each location?" is non-spatial question.

1.5 Components of GIS

A GIS is comprised of hardware, software, data, humans, network and a set of organizational protocols called method that make it possible to enter, manipulate, analyze, and present information that is tied to a location on the earth's surface (Figure 3). These components must be well integrated for effective use of GIS, and the development and integration of these components is an iterative and ongoing process.

Fig 3. Components of GIS

A. People

People refer users and can be considered as the component of GIS who actually makes the GIS work. GIS technology has limited value without the people who manage the system and develop plans for applying it to real-world problems. Most GIS also require trained personnel to use them, and a set of protocols guiding how the GIS will be used. People in GIS usually include excess of positions including GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for maintenance of the geographic database and provide technical support. People also need to be educated to make decisions on what type of system to use. People associated with a GIS can be categorized into: viewers, general users, and GIS specialists

B. Hardware

Hardware consists of the computer system on which the GIS software will run. It is the computer on which a GIS operates. Today, GIS runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations. That means the choice of hardware system range from 300MHz Personal Computers to Super Computers having capability in Tera storage capacity. Normally large storage capacity hardware does have high speed of data execution.

Components of hardware

The central processing unit forms the backbone of the GIS hardware. Other components include scanner, digitizer board, printer, plotter, and storage devices. All these components should be connected to the CPU. The above mentioned hard wares are discussed below.

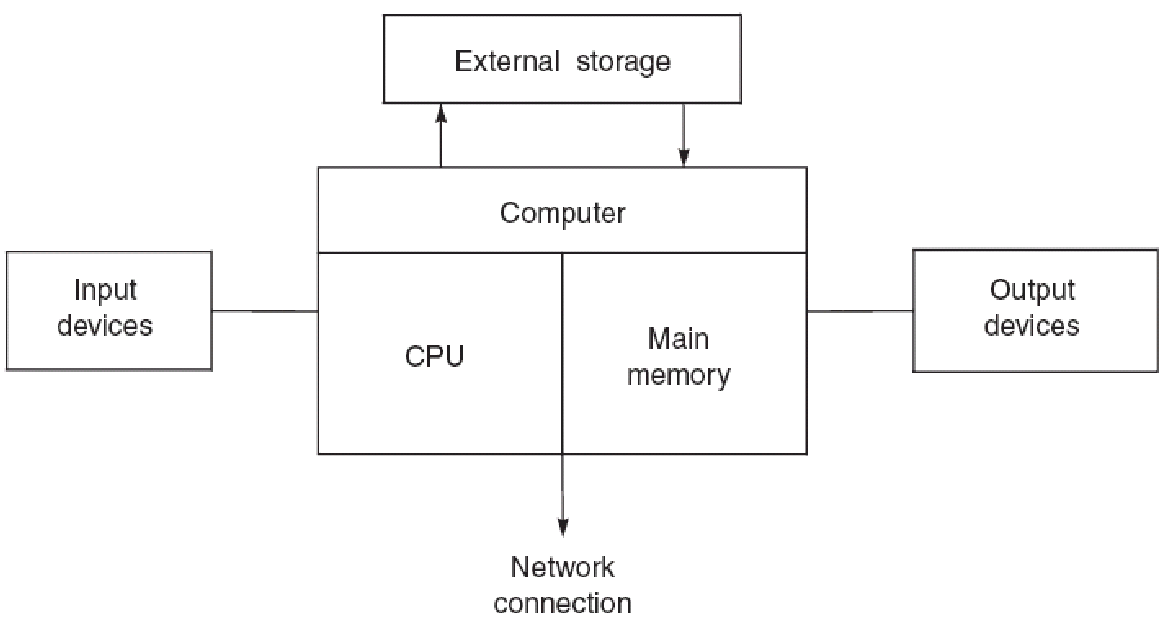

Fig 4. Components of hardware

Scanner – it is input device that converts a picture in analogue format into a digital image for further processing. The output of scanner can be stored in many formats e.g. TIFF, BMP, JPG etc.

ii. Digitizer – it is input device used for vectorization (it is a process of converting raster into vector format) of a given map objects. Features either on paper map or digital map selectively can be traced using digitized.

iii. Printers and plotters - are the most common output devices for a GIS hardware setup.

iv. Storage devices - Storage devices are hardware designed to store information. There are two types of storage devices used in computers; a 'primary storage' device and a 'secondary storage' device. A storage location that holds memory for short periods of times is an example of a primary storage device for example, computer RAM. On the other hand, storage medium that holds information until it is deleted or overwritten is an example of secondary storage devices. Examples include floppy disk drive or a hard disk drive.

The essential hardware elements for effective GIS operations include:

a) The presence of a processor with sufficient power to run the software

b) Sufficient memory for the storage and backup of large volumes of data

c) A good quality, high resolution color graphics screen or monitor and

d) Data input and output devices, like keyboards, printers and plotters.

C. Software

Software that is used to create, manage, analyze and visualize geographic data, i.e. data with a reference to a place on earth, is usually denoted by the umbrella term ‘GIS software’. Typical applications for GIS software include the evaluation of places for the location of new stores, the management of power and gas lines, the creation of maps, the analysis of past crimes for crime prevention, route calculations for transport tasks, the management of forests, parks and infrastructure, such as roads and water ways, as well as applications in risk analysis of natural hazards, and emergency planning and response. For this multitude of applications different types of GIS functions are required and different categories of GIS software exist, which provide a particular set of functions needed to fulfill certain data management tasks.

GIS software provides the tools to manage, analyze, and effectively display and disseminate spatial data and spatial information. Main function of GIS software are analytical functions that providemeans for deriving new geo-information from existing spatial and attribute data. GIS by necessity involves the collection and manipulation of the coordinates the GIS professionals use to specify location. It is also must to collect qualitative or quantitative information on the non-spatial attributes of our geographic features of interest. These processes need tools to view and edit these data, manipulate them to generate and extract the information we require, and produce the materials to communicate the information developed. GIS software provides the specific tools for some or all of these tasks.

In GIS software geographic objects that have the same geometric and attribute representation are typically grouped in so-called 'layers' to simplify data management tasks. For instance, all buildings that are represented by polygons and have information on owner and construction year are grouped in a layer 'buildings'. The typical graphical user interface of a GIS software package that includes the concept of geometries (map view) connected to values in tables (attribute view); as well as layers that contain one class of objects (e.g. rivers).

Typical Tasks Accomplished with GIS Software

Before any geographic analysis can take place, the data need to be derived from field work, maps or satellite imagery, or acquired from data providers. Hence, data need to be created, and - in case something has changed – the data should be edited, and then stored. If data are obtained from other sources they need to be viewed and eventually integrated (conflation) with existing data. To answer particular questions, e.g. who is living in street X and is affected by the planned renewal of a power line, the data are queried and analyzed. However, some specific analysis tasks may require a data transformation and manipulation before any analysis can take place. The query and analysis results can finally be displayed on a map. In general, the GIS software functional elements include:

- ✓ Data input
- ✓ Data storage and database management
- ✓ Data pre-processing/ processing
- ✓ Data analysis, manipulation, and modeling
- ✓ Data output

Reading assignment, explain in detail about GIS software functional elements?

There are many public domain and commercially available GIS software packages, and many of these packages originated at academic or government-funded research laboratories. The Environmental Systems Research Institute (ESRI) line of products, including Arc/Info, is a good example. Much of the foundation for Arc/Info was developed during the 1960s and 1970s at Harvard University in the Laboratory of Computer Graphics and Spatial Analysis. Other GIS software's in use are Arc GIS, IDRISI, and EARDAS IMAGINE.

D. Data

Geographic data and related tabular data can be collected in-house or purchased from other organizations and can be compiled to custom specifications and requirements, or occasionally purchased from a commercial data provider. A GIS can integrate spatial data with other existing data resources, often stored in a corporate Database management system (DBMS). The integration of spatial data (often proprietary to the GIS software), and tabular data stored in a DBMS is a key functionality afforded by GIS. Like all useful data, geographic data is expected to possess desirable properties of accuracy, timeliness, comprehensiveness, acceptable cost etc. Other general issues relating to geographic data include spatial extent (the area covered), scale (the detail in the system), the large volume (both attribute data and graphic data can make large storage demands), diversity (data of interest plus background data), collection cost (despite technological advances, field collection of data can still be very labor intensive), etc. Scale is important not only for graphic representation in map form but also as it impacts on other issues such as map coverage extent, data volume and data collection. The concept of a data model is central to any discussion of geographic data i.e. there is need to convert/translate the complexity of the real world into a simplified model. This model, in turn, should preferably be amenable to the recording of data in a computer eg. as a field in a table. A data model in GIS consists of a measurement framework and a scheme for representation (spatial, temporal and attribute). Measurement metrics of attribute data (e.g. nominal, ordinal, interval, ratio etc) has important implications for operations involving attribute data manipulation. Need to understand that within this framework the data collection procedure and the collection unit used can seriously impact on data quality.

Major sources of geographic information: maps, aerial photographs, remotely sensed imagery and digital datasets available from various vendors. It is important to note the source of all data sets and keep in mind issues such as scale, resolution, map projection, and date. These elements should

be recorded in a metadata record, which documents different aspects of a data set, including source, projection, and contact information.

E. Procedures /Applications Procedures

Include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the steps taken to answer the question need to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information systems. Generally,

• Analysis requires well-defined, consistent methods to provide accurate and reproducible results.

• Whether the application is simple data tracking or complex multidimensional analysis, a GIS should be designed with the potential applications in mind.

• Applications of geographic information to real world problem solving is the heart of any GIS.

1.6 Application Areas of GIS

GIS are now used extensively in government, business, and research for a wide range of applications including:

- Land registration and administrations
- Utility and infrastructure planning
- Land registration and administrations
- Real estate analysis
- Land use planning
- Marketing and demographic analysis
- Locational analysis
- Habitat studies, and
- Tax appraisal
- Archaeological analysis

❑ In natural resource management

➢ Watershed management

➢ Mineral and other resource exploration and utilization

➢ Forest resource monitoring

➢ Agricultural land suitability analysis

➢ Land cover change analysis

➢ Mining

➢ Land use planning

➢ Protected area management

In Industry and Urban Planning

➢ Transportation analysis

➢ Locating underground pipes and cables

➢ Engineering

➢ Balancing loads in electrical networks

➢ Residential and commercial land suitability analysis

➢ Utilities and communications

➢ Planning facility maintenance

➢ Project planning and analysis

➢ Tracking energy use

❑ In Environmental Protections

- ➢ Erosion risk analysis
- ➢ Healthcare analysis
- ➢ Drought analysis
- ➢ Crime analysis
- ➢ Landslide analysis
- ➢ Hazard analysis and mapping

❑ In Military

- ➢ Training
- ➢ Command and control
- ➢ Intelligence gathering

❑ In Business

- ➢ Banking and insurance
- ➢ Delivery of goods and services
- ➢ Retails and market management